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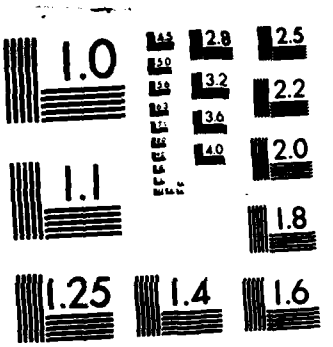

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

LANDSAT exploitation for hydrographic support has been under study and in use on a limited scale for some time. The Defense Mapping Agency(DMA) has found LANDSAT's multispectral scanner imagery particularly useful in augmenting the completeness of its products. Recently, a program has been implemented using this remotely sensed imagery in routinely updating and maintaining nautical charts and publications. This paper provides a general description of the LANDSAT system and applications at DMA as well as limitations of its use in navigation.

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USE OF LANDSAT FOR NAVIGATION PRODUCTS AT DMA

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Abstract

LANDSAT exploitation for hydrographic support has been under study and in use on a limited scale for some time. The Defense Mapping Agency (DMA) has found LANDSAT's multispectral scanner imagery particularly useful in augmenting the completeness of its products. Recently, a program has been implemented using this remotely sensed imagery in routinely updating and maintaining nautical charts and publications. This paper provides a general description of the LANDSAT system and applications at DMA as well as limitations of its use in navigation.

Introduction

The Defense Mapping Agency is responsible for providing information for the

navigational safety of U. S. Navy ships and mariners in general on a worldwide basis. This responsibility is carried out by disseminating information to the navigators via nautical charts, navigation publications, and daily radio navigation warnings. Failure to make use of available data when compiling these products and services may adversely affect the safety of lives and property at sea. Consequently, new information sources are constantly being reviewed to aid DMA in fulfilling its mission. LANDSAT imagery is one such information source. It has proven to be a useful addition to other source material in the compilation of nautical charts and also in the detection and verification of navigational hazards. Efforts continue to develop new means of using this unique type of satellite imagery.

LANDSAT Background

In the past ten years, four LANDSAT satellites have been launched which provide a data bank covering most of the world at various times of the year. (Figures 1 and 2) The primary sensor aboard every LANDSAT satellite is the Multispectral Scanner (MSS). This sensing instrument has detectors which are sensitive to a narrow portion of the electromagnetic radiation (EMR) spectrum. The four bands on the MSS have the following wavelengths:

Band	Wavelength	Maximum Water Penetration (ideal conditions)
4	0.5 - 0.6 micrometers	40.0 meters
5	0.6 - 0.7 micrometers	8.0 meters
6	0.7 - 0.8 micrometers	0.5 meters
7	0.8 - 1.1 micrometers	0.0

When sunlight passes through a column of water, reflections off the seafloor or a shoal area are returned to a detector where it creates a voltage signal and then transforms it into a digital value, (Figure 3). Clarity of the water, bottom reflectance, and wavelength

Launch History of Landsat Observatories

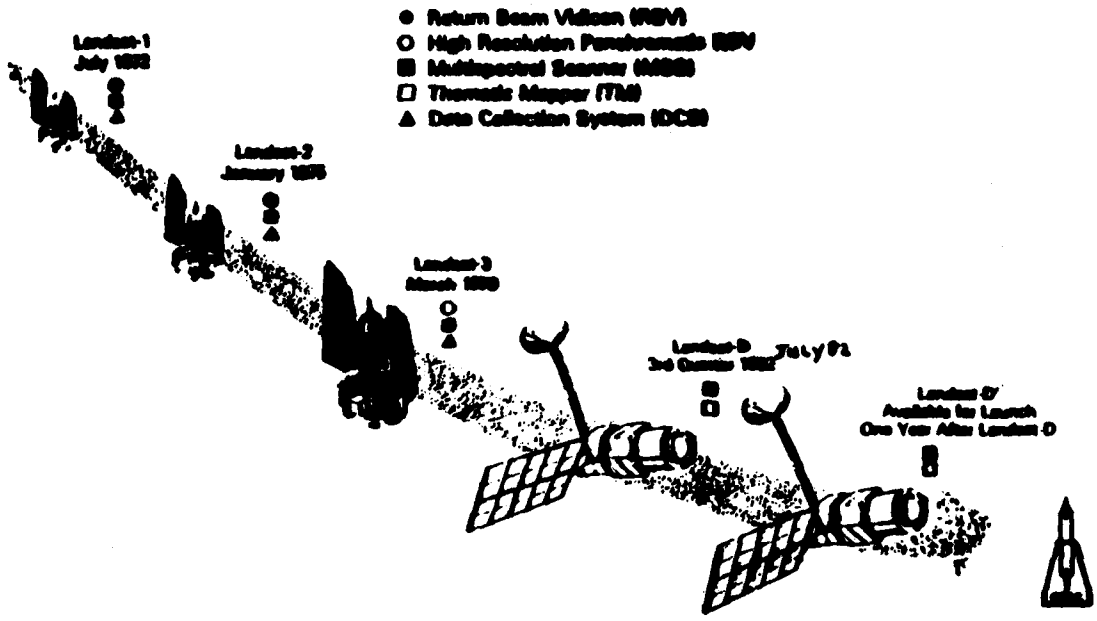


FIGURE 1

Typical Landsat Daily Ground Trace (Daylight Passes Only)

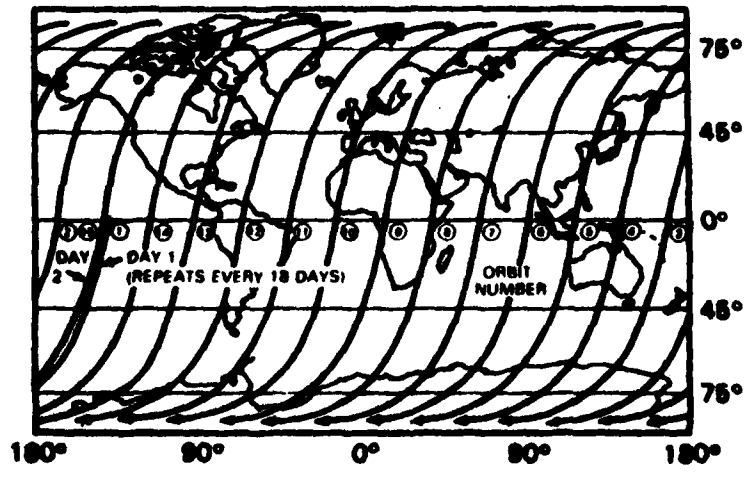


FIGURE 2

MSS Scanning Arrangement

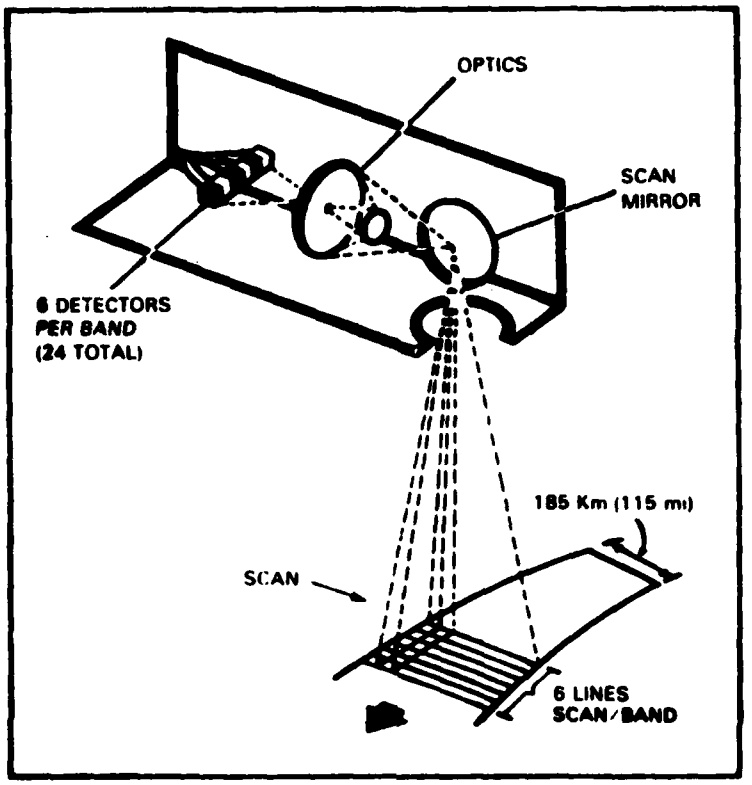


FIGURE 3

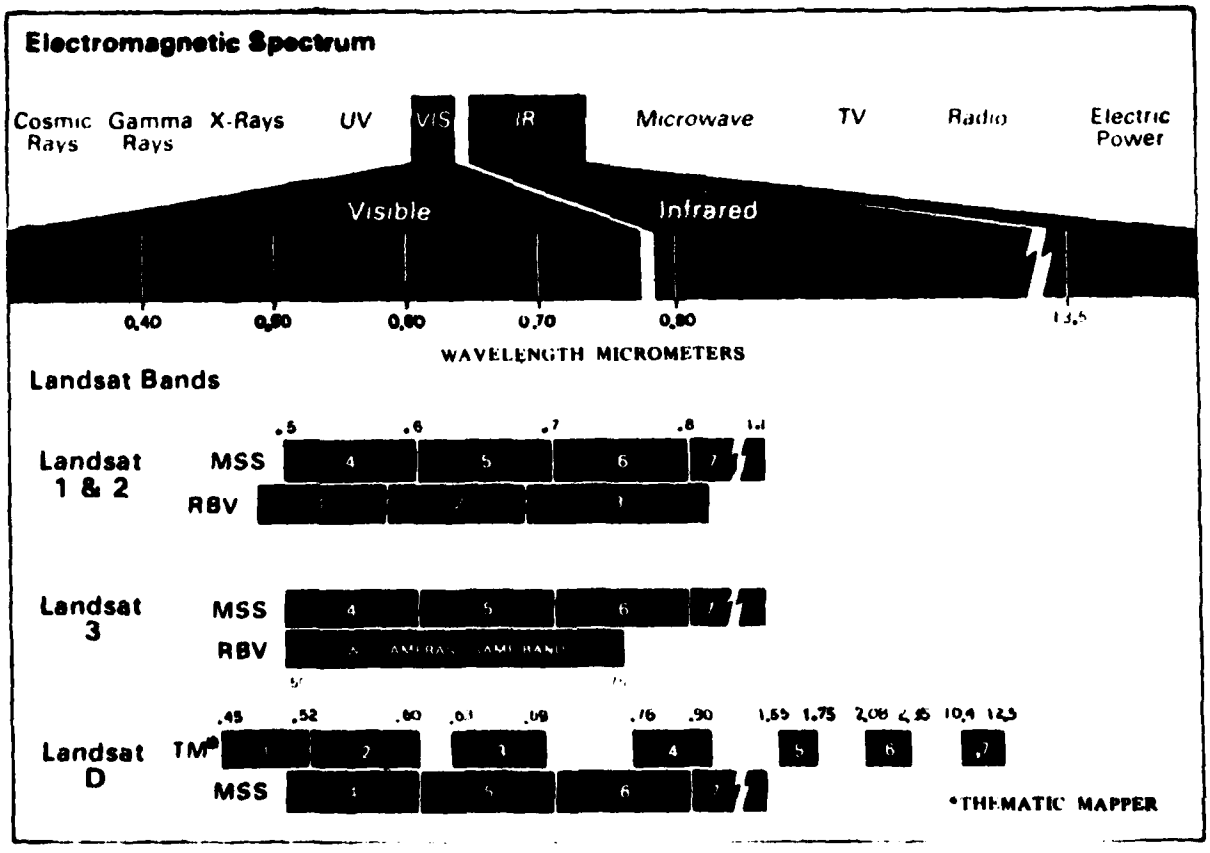
affect the propagation of light through water. Under ideal conditions, the light reflected off the bottom of the ocean can permit imaging of features as deep as 40 meters for band 4. Band 5 can detect to about 8 meters and band 6 to 1/2 meter. Band 7 shows no subsurface features.

MSS data from the satellite are transmitted to one of several U. S. and foreign ground receiving stations. These data are then sent to the Goddard Space Flight Center in Greenbelt, Maryland, where they are recorded on High Density Tapes. From there, the data are transferred to the EROS (Earth Resources Observation System) Data Center in Sioux Falls, South Dakota for image enhancement as well as radiometric and geometric corrections. EROS distributes the final product in the form of computer-compatible

digital tapes (CCT's) or film positives.

Recently, National Aeronautics and Space Administration (NASA) transferred operational management of LANDSAT to National Oceanographic and Atmospheric Administration (NOAA) who will eventually pursue commercialization of the system. LANDSATs 1 and 2 are no longer operational and LANDSAT 3 was turned off earlier this year. The MSS system on LANDSAT 4 is managed by NOAA, while NASA retains management control of the new Thematic Mapper sensor system during the experimental research and development phase.

The Thematic Mapper (TM) is a new earth observing sensor launched on LANDSAT 4 in July 1982 with many improved capabilities. The TM measures surface radiation in 7 spectral bands compared to 4 on the MSS, (Figure 4).



Landsat Bands and Electromagnetic Spectrum Comparison

FIGURE 4

LANDSATs 1, 2, and 3 had a nominal pixel size of 57 x 79 meters, and therefore were not usually able to delineate areas smaller than about one acre on a side; spatial resolution of TM picture elements is 30 x 30 meters. Another vast improvement with the Thematic Mapper is the increased sensitivity to 256 gray levels in each spectral band; whereas, the MSS is sensitive to only 64 gray levels. Consequently, the Thematic Mapper provides significant improvements in spectral resolution, spatial resolution, and sensitivity.

At present, there are two major problems with the Thematic Mapper that have prevented reception of TM data since January 1983. A malfunction in the transmitter onboard the LANDSAT satellite will not allow TM data to be transmitted directly to ground receivers. The Tracking and Data Relay Satellite System (TDRSS), which was launched during the 6th Space Shuttle mission, is not in the proper orbit. Consequently, data cannot be transferred via the TDRSS to the ground receiving stations. There is also a problem with the onboard power source. It is hoped that these problems will be corrected in the next few months and TM data collection will be resumed. In the meantime, DMA concentrates on the exploitation of existing MSS data that are readily available.

Applications at DMA

Two important characteristics make LANDSAT imagery particularly useful in hydrographic applications. First, multi-temporal coverage, or imagery of the same area at different times of the year, makes it possible to detect changes in dynamic areas and increases the possibility of cloud-free coverage. Second, LANDSAT has the unique capability of showing features that lie below the surface of the water. This is especially useful to the chart compiler in shallow ocean areas.

In the Navigation Department at DMA, efforts are being concentrated on developing a quick response to ship reports and radio messages citing a navigational hazard. The type of hazards investigated are newly discovered or shifting shoals, reefs, and islands. If inspection of LANDSAT imagery verifies that the hazard exists, immediate action is taken to alert all mariners and correct the chart. The following list of radio warnings from the Worldwide Navigation Warning System shows potential dangers which could be investigated with LANDSAT.

1. 420/82(19). HAWAIIAN ISLANDS.
   1. Possible uncharted shoal reported in 21-20N. 163-11W.(PA).
   2. Cancel NAVAREA XII 419/82(18) and this paragraph, aid normal.
   (CCGD FOURTEEN 0801111Z MAY 82)
   (CCGD THIRTEEN 607/82) (082230Z May 1982)

2. 914/82(37). ENGLAND - EAST COAST.
   Chart 37170.
   Less water than charted reported vicinity 52-55.8N. 01-24.2E.
   (NAVAREA ONE 150/82) (041420Z Jun 1982)

3. 979/82(57). SOUTHWEST AFRICA - NAMIBIA.
   Chart 57380.
   Shoal, least depth 13 meters, reported 21-54.2S. 14-00.8E.(PA).
   (NAVAREA VII 54/82) (152025Z Jun 1982)

4. 1719/82(24). VENEZUELA, ISLA DE MARGARITA.
   Vessel reported striking submerged object about 8.65 miles 099 degree from Robledor (11-02.6N. 64-23.0W.).
   (CODE NVS) (151800Z Jun 1982)

5. 2199/82(28). BAY OF CAMPECHE.
   Chart 28029.
   Depth. 13 fathoms 2 feet reported in 21-55.2N. 92-19.1W.(PA).
   (COMLANTAREA COGARD 240654Z JUL 82) (261315Z Jul 1982)

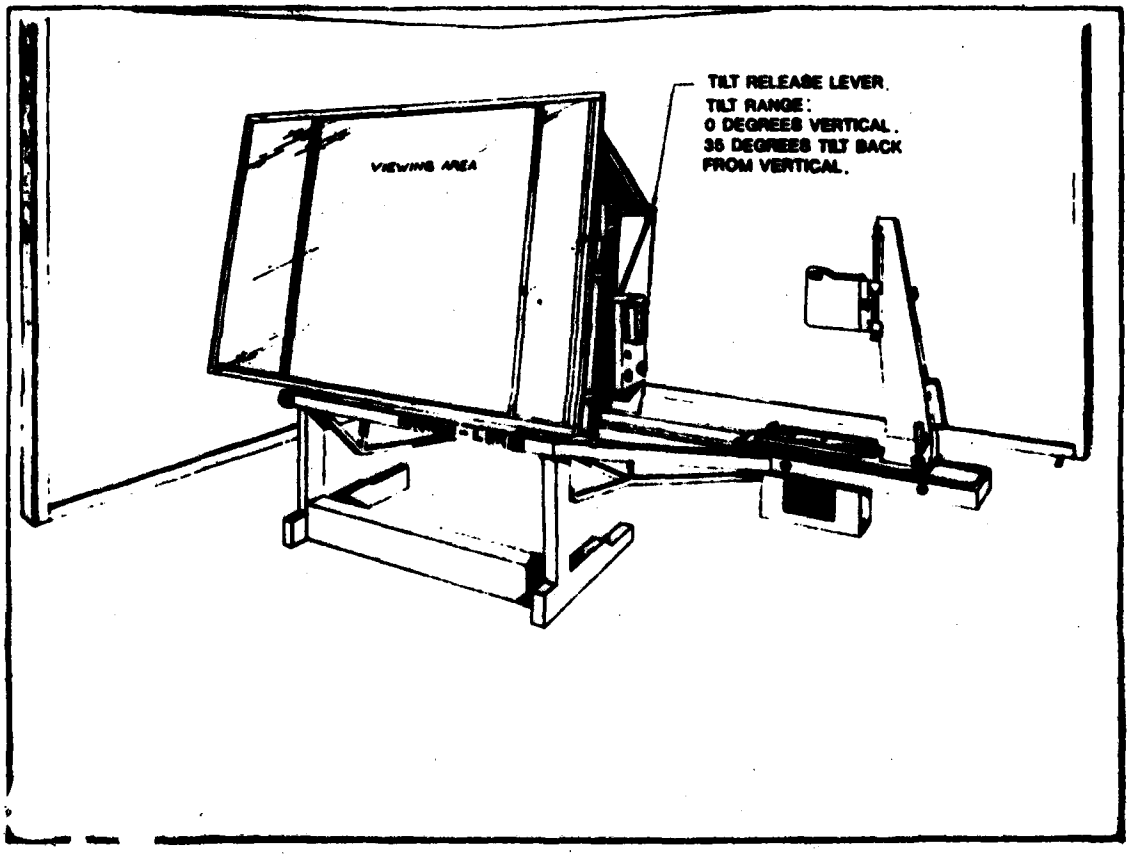
At present, only analog methods are used by the Navigation Department to verify isolated hazards using LANDSAT. However, the Hydrography Department of DMA does use computer-compatible tapes for digital image processing in charting large ocean areas.

The major pieces of equipment used for analog analysis from LANDSAT film positives or negatives (241mm or 70mm) are a Multiscale Projector/Viewer (MSP/V), and a Color Additive Viewer (CAV). Much of the LANDSAT imagery collected since 1972 is available

in-house at DMA or may be borrowed from other agencies in the Washington, D.C. area. As a last resort, the film can be ordered from the EROS Data Center in Sioux Falls. But due to price increases and a six week delivery period, this process reduces DMA's effectiveness to provide a quick response.

The Multiscale Projector/Viewer (Figure 5) is a precision rear projection system for viewing photographic negatives or positives at any desired scale. This capability is useful in comparing the image with nautical charts. The optical system is used to adjust an image to the proper chart scale and project it onto the viewer's rear surface. A stable base transparency of the affected nautical chart is overlayed on the viewer's front surface. The image is rotated and/or tilted to obtain a local fit to the chart. Discrepancies between the image and the chart such as positioning of islands and reefs, shape of coastline, and existence or absence of shoals will become obvious by simple inspection.

FIGURE 5



There are 5 projector heads on the MSP/V providing magnification from 2 to 75 times. Either 241mm or 70mm film chips can be inserted in the projector. For LANDSAT applications, there is little use for enlargements greater than 10 times. An approximation of the enlargements can be determined by the following formula:

$$\text{Degree of enlargement} = \frac{\text{image scale}}{\text{chart scale}}$$

The 241mm (9" x 9") film is at a scale of 1:1,000,000 and the 70mm film is at a scale of 1:3,300,000. Minute adjustments in scale and focus can be made mechanically using levers on the side of the optical table.

The second major piece of equipment used for imagery analysis is the Color Additive Viewer (CAV - Figure 6). The CAV is a projector with 5 light channels in which 70mm film chips can be inserted. The image is enlarged 3.3 times and can be color enhanced in each channel with blue, green, and red filters. Potentiometers control the light intensity on each channel. There is also a flicker switch which will blink any selected channel out of phase with the other channels. By inserting bands 4, 5, and 7 of the same image and assigning each band a different color, the interpreter is aided in distinguishing shoals from clouds and surface turbidity. Submerged features will only appear on band 4 and possibly band 5; whereas, clouds and surface turbidity will be on all bands. Another method of determining cloud cover is to insert an image of the same scene taken on a different day in the fourth or fifth channel. Temporary features such as clouds can be classified by using a white light on the various bands of one day and a red light on the second day image.

Limitations

It is important to understand the limitations of satellite imagery in relation to

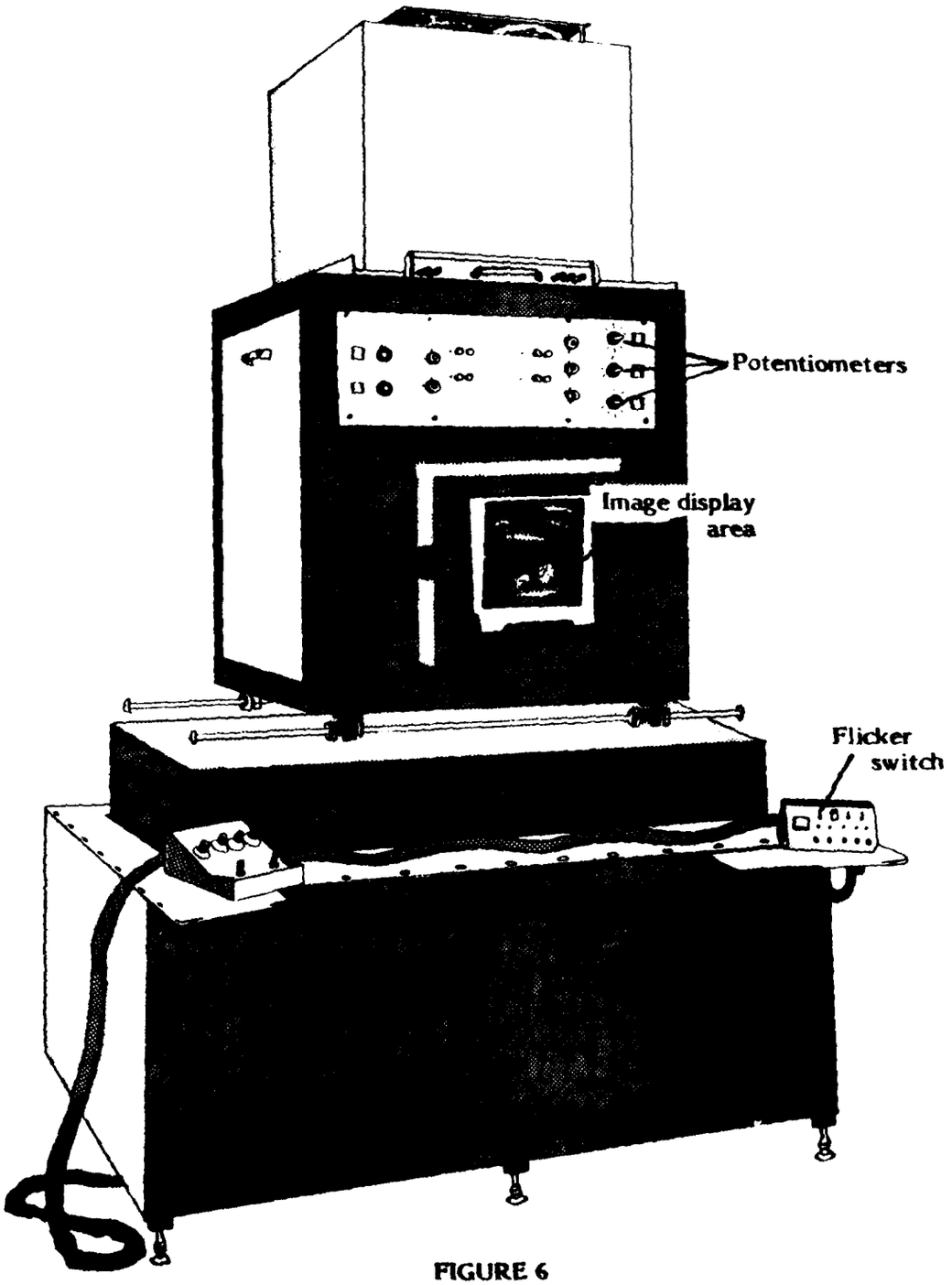


FIGURE 6
COLOR ADDITIVE VIEWER

navigation products. The primary concern in using LANDSAT is obtaining the required imagery. Although a large data bank of images exists, it is not always readily available or in the correct format for interpretation. Periodically, the imagery must be photographically reproduced from a film roll. This delay in the photo lab reduces the effectiveness of DMA's quick response to navigational hazards. In addition, there may be a number of images available for the area under investigation, but cloud cover and poor image quality may prevent analysis of the feature in question.

Even though LANDSAT provides information on remote areas where no other sources exist, these remote areas often lack geodetic control. Consequently, positions of islands and shoals must be approximated. In open ocean areas where only isolated reefs and islands appear on the image with no major coastline, positioning may be impossible with LANDSAT as a sole source.

Results

Since the implementation of the LANDSAT program in the Navigation Department less than a year ago, several important refinements have been made to DMA products. If the nautical chart requiring a modification is in some phase of compilation or revision, the change can be made before the chart is printed. A newly discovered or reconfigured feature in a high traffic area is considered an immediate danger, so a radio warning to ships at sea will be broadcast. A weekly Notice to Mariners chart amendment may follow to amplify and replace the radio warning. In some cases, it will not be necessary to precede the Notice to Mariners with a radio warning. The discovery of a new feature or change to an existing one may also be incorporated into the Sailing Directions and other related publications of the affected area.

LANDSAT imagery provides a unique capability for the collection of useful data covering shallow sea areas worldwide. Investigations of its use by the Navigation Department of DMA have proven that LANDSAT is effective in the detection and verification of navigational hazards. More efficient response methods and advanced analytical techniques are continuing to be explored. Because of the success in improving DMA's products, LANDSAT usage will continue in the Navigation Department.

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